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DEVELOPMENT AND IMPLEMENTATION OF ENVIRONMENTALLY COMPATIBLE SOLID FILM LUBRICANTS

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ABSTRACT

Multi-body launch vehicles require the use of Solid Film Lubricants (SFLs) to allow for unrestricted relative motion between structural assemblies and components during lift-off and ascent into orbit. The Space Shuttle Solid Rocket Booster (SRB), uses a dual coat, ceramic-bonded high temperature SFL in several locations such as restraint hardware between the SRB aft skirt and the Mobile Launch Platform (MLP), the aft SRB/External Tank (ET) attach struts, and the forward skirt SRB/ET attach ball assembly. Future launch systems may require similar applications of SFLs for attachment and restraint hardware. A family of environmentally compatible non-lead/antimony bearing alternative SFLs have been developed including a compatible repair material. In addition, commercial applications for SFLs on transportation equipment, all types of lubricated fasteners, and energy related equipment allow for wide usage's of these new lubricants. The new SFLs trade named BOOSTERLUBE is a family of single layer thin film (0.001 inch maximum) coatings that are a unique mixture of non-hazardous pigments in a compatible resin system that allows for low temperature curing (450°F). Significant savings in energy and processing time as well as elimination of hazardous material usage and disposal would result from the non-toxic one-step SFL application. Compatible air-dry field repair lubricants will help eliminate disassembly of launch vehicle restraint hardware during critical time sensitive assembly operations.

INTRODUCTION

USBI Co. is responsible for the assembly and refurbishment of the non-motor components of the SRB as part of the Space Shuttle system shown in Figures 1 and 2, and which is developed and managed by Marshall Space Flight Center (MSFC) in Huntsville, Alabama. Programs are underway to develop and evaluate environmentally acceptable SFLs for use on aerospace flight hardware in order to eliminate lead, mitigate corrosion by substitution of graphite pigments, and ultimately extend the useful service life of these unique and expensive hardware items. Figure 3 shows the typical areas of lubricant application on SRB flight hardware. All SRB bearing material is made from Inconel 718 which interfaces with either Inconel 718 or 15-5 P.H. materials. The initial study focused on the replacement of a lead bearing dual coat SFL with that of a unique environmentally compatible single coat system. The existing dual coat SFL system required a complex masking and basecoat application and then curing at 1000°F, followed by additional masking and the application of a topcoat followed by a second curing operation at 500°F. The basecoat contains lead and other hazardous air pollutants as does the topcoat and extensive precautions are taken during the application and disposal of such materials. The new family of single coat SFLs named BOOSTERLUBE do not contain lead or hazardous air pollutants and can be easily applied in a single step with curing at 450°F. The new SFL also had to be compatible with the existing production equipment at Kennedy Space Center in order to make the process economical. Subsequent application of SFLs to all qualification test articles were performed by production technicians at USBI Co. production facilities.

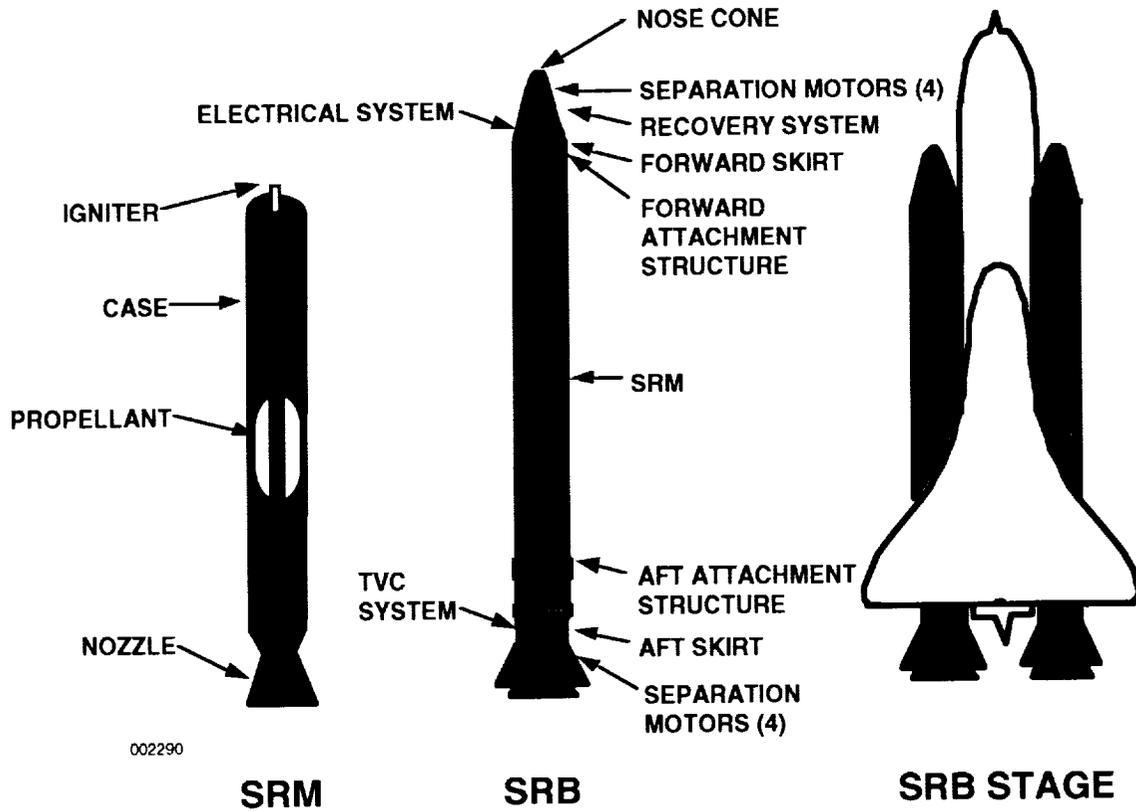


Figure 1. Space Shuttle's SRB

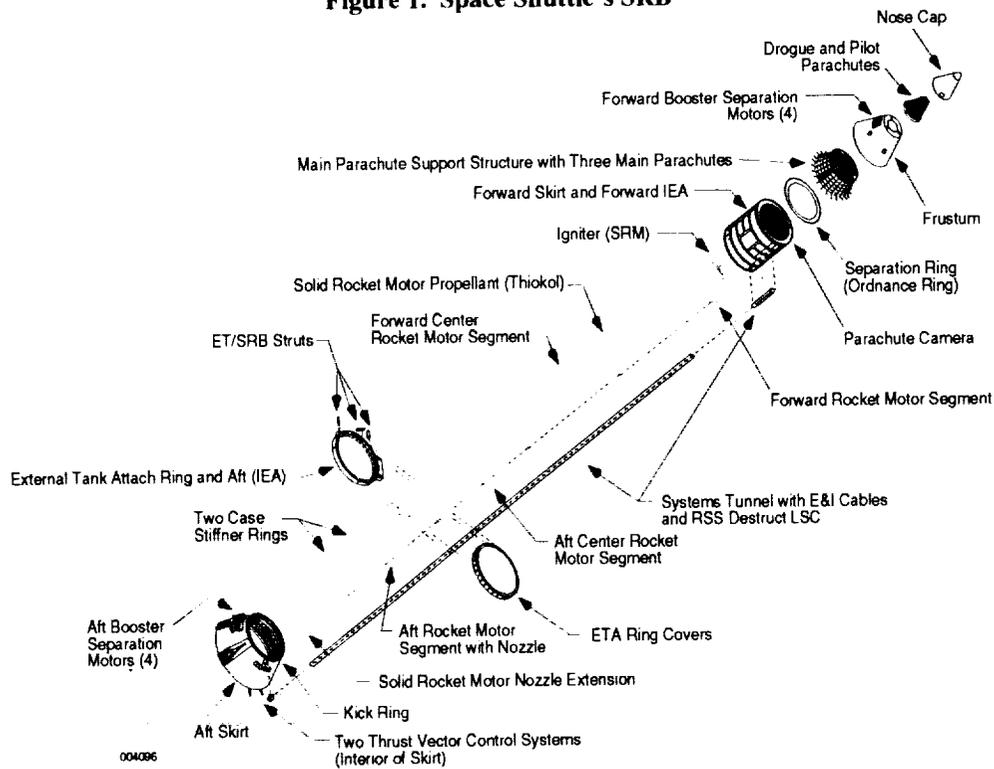


Figure 2. Solid Rocket Booster

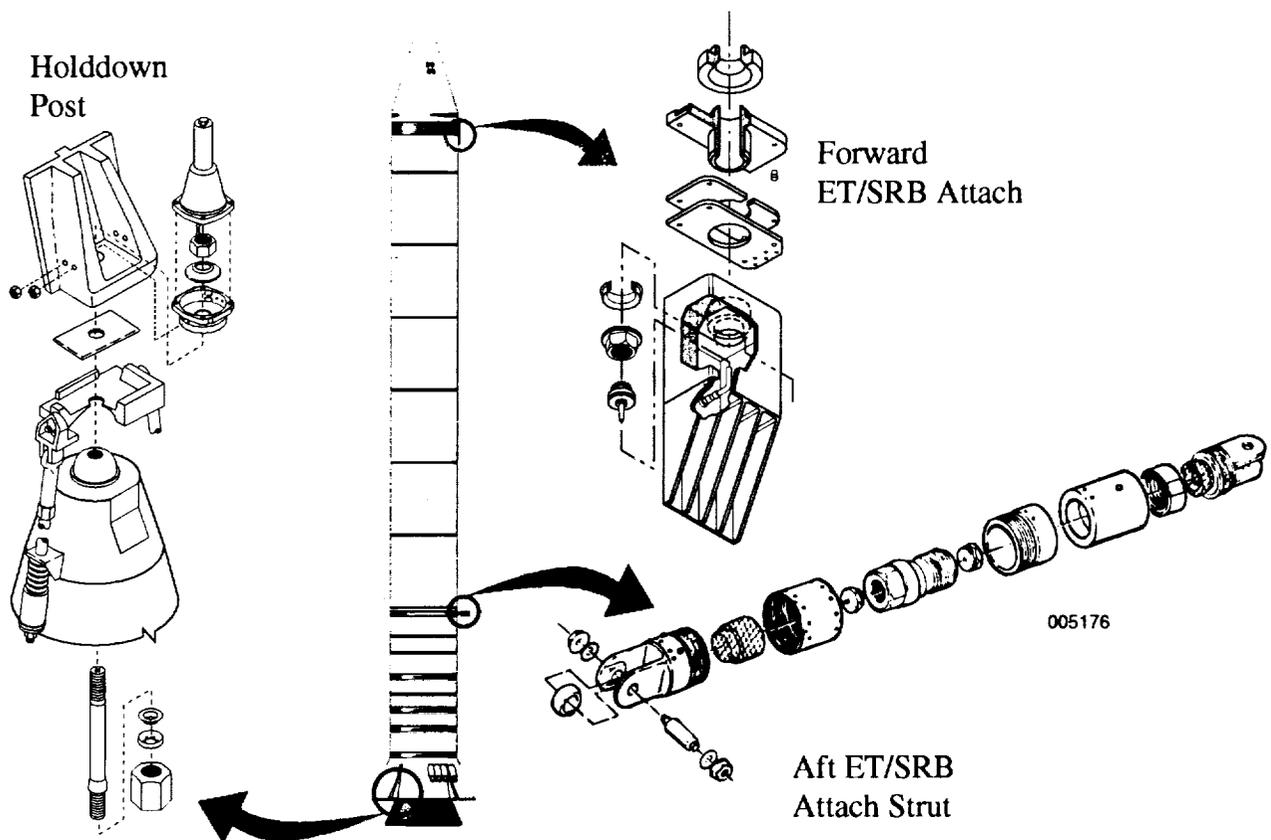


Figure 3. Typical Areas of Lubricant Application on SRB Flight Hardware

DISCUSSION

Pigment and Resin Evaluation and Selection

The first phase of this program involved the selection and screening of five resin systems consisting of epoxy, silicone, phenolic, polyimide and epoxy/silicone blends. Pigments consisting of molybdenum disulfide, graphite, antimony trioxide, lead oxide and boron oxide were all evaluated. The existing dual coat ceramic bonded lead oxide bearing system was used as a baseline for coefficient of friction, load bearing capacity, and endurance life. Testing of the various SFL systems were performed in accordance with ASTM D 2625 Parts A & B (1) (Falex Pin and V-Blocks, testing endurance life and load carrying capacity) as shown in Figure 4; ASTM D 2714 (1) (Falex Block-on-Ring, testing coefficient of friction and wear life) shown in Figure 5, and a mono-ball test developed by MSFC shown in Figure 6. The MSFC mono-ball test simulates the very high load conditions at the holddown post and upper external tank attach point, and is the most critical of all tests for verifying SFL performance. Screening the above lubricant systems resulted in the selection of an epoxy/silicone resin blend with pigments consisting of molybdenum disulfide, graphite, and boron oxide. The substitution of graphite with boron oxide, where required, provided a means of eliminating galvanic corrosion when in contact with dissimilar metals in a sea water or salt fog environment. Development of a new device for extreme pressure testing of SFLs allowed USBI Co. and MSFC to run their test programs in parallel, thus saving many months of serial time.

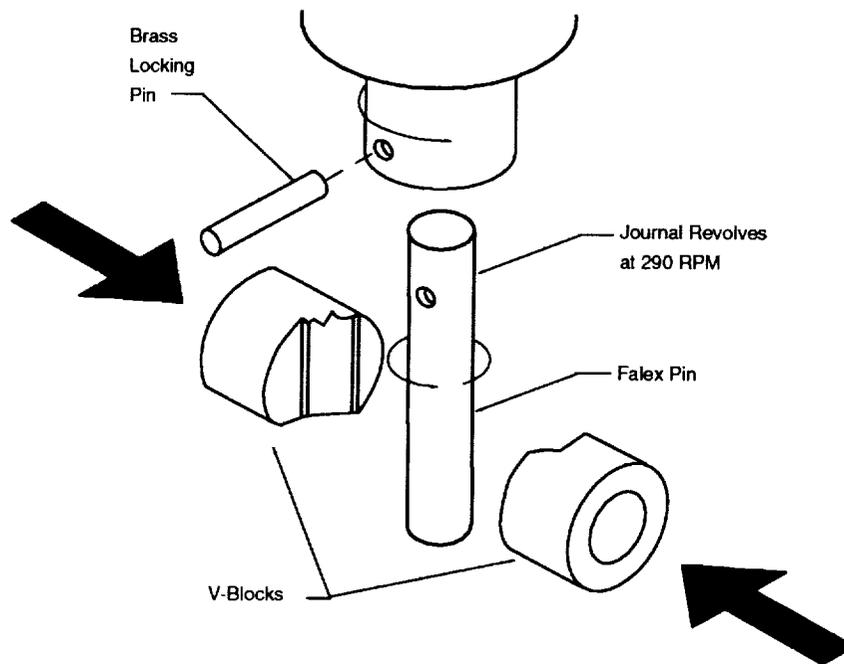


Figure 4. Standard Falex Pin and V-Blocks for Lubrication Tests

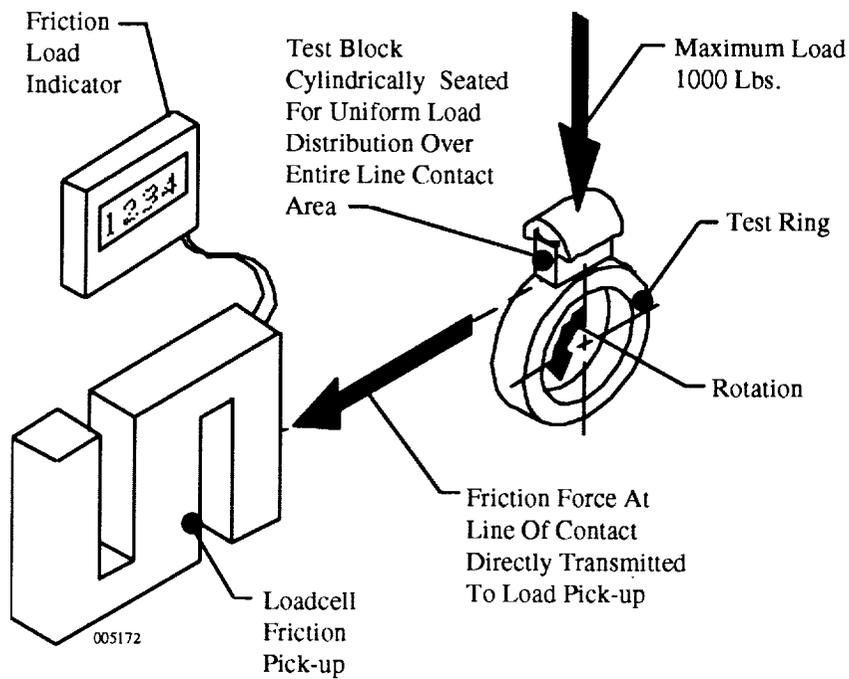


Figure 5. Function Diagram of the Falex Block-On-Ring Testing Machine

Test Results

Initial testing of BOOSTERLUBE properties at the manufacturer's site, using the Falex Pin and V-Block, ASTM D 2625 Parts A & B and the Falex Block-on-Ring, ASTM D 2714 confirmed the acceptable properties of the Silicone/Epoxy resin system. The Block-on-Ring test showed an improvement in wear life of the BOOSTERLUBE materials as compared to the Ceramic Bonded dual coat SFL. Coefficients of friction (μ) were 0.8 - 0.12 and durability of the new SFLs were excellent as confirmed by burnishing with a lint-free cloth. One of the problems associated with the original dual coat system was the relatively soft topcoat that was prone to damage. Significant inspection time was required to determine whether surface marks were caused by actual damage or by burnishing during normal handling. BOOSTERLUBE is a tougher resin system and is less susceptible to marking and/or damage. A compatible air dry repair lubricant was also developed to allow for minor area repairs to lubricated parts that are inadvertently damaged in the field. Final tests of BOOSTERLUBE were performed on optimized pigment volume concentrations using MoS₂/graphite and MoS₂/boron oxide. This, in combination with optimum blends of silicone and epoxy resin systems, allowed for tailoring properties to their required applications. All test specimens were precision cleaned, grit blasted, lubricated, and oven cured by production technicians and on production line facilities at USBI Co. operations. Specimens were then sent to MSFC, Tribology Labs. for qualification testing. The most relevant of all tests, MSFC/EH14 High Load Test (mono-ball test) showed superior properties of BOOSTERLUBE (WL-1158-20) over the existing ceramic bonded dual coat SFL, a material that also contains lead and hazardous air pollutants.

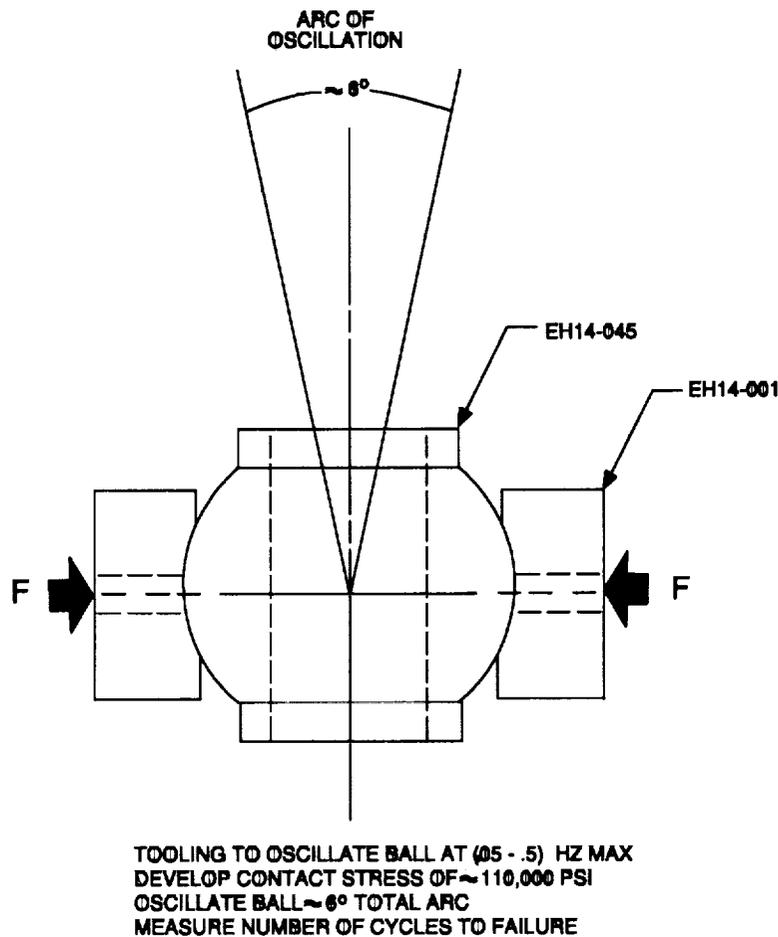


Figure 6. MSFC/EH14 High Load Test (110 KSI)

CONCLUSION

Development and testing of a new family of environmentally compatible SFLs allowed for the potential replacement of lead bearing, hazardous air polluting, energy inefficient, SFL materials. The single coat SFL named BOOSTERLUBE, showed excellent performance as compared to other lubricant systems and met with significant operator acceptance. Eliminating lead exposure to personnel during application and disposal of those materials was in itself a major accomplishment. The economics of a single coat system will cut application costs as well as energy related charges for SFL curing, by 50%. The costs of disposing of and utilizing hazardous materials continue to escalate and in time will be prohibitive. Applications for many other fields than aerospace exist. Energy and power generation, chemicals, transportation, machinery of all types, exo-atmosphere and low earth orbit vehicles can benefit from implementation.

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